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I HEREBY CERTIFY that annexed hereto is a true copy of documents filed in connection with the following patent application:

| | |
|---|---|
| Application No. | 2000/0320 |
| Date of Filing | 28 April 2000 |
| Applicant | MASSANA RESEARCH LIMITED, an Irish company of 5 Westland Square, Dublin 2, Ireland. |

Dated this 26 day of March 2001.

Claire O' Reilly

pp An officer authorised by the
Controller of Patents, Designs and Trademarks.

FORM NO. 1

F 000320

# REQUEST FOR THE GRANT OF A PATENT

## PATENTS ACT, 1992

The Applicant(s) named herein hereby request(s)

__X__ the grant of a patent under Part II of the Act

______ the grant of a short-term patent under Part III of the Act

on the basis of the information furnished hereunder.

1. Applicant(s)

Name Massana Research Limited

Address 5 Westland Square
Dublin 2
Ireland

Description/Nationality

An Irish company

2. Title of Invention

"Echo and Crosstalk Cancellation"

3. Declaration of Priority on basis of previously filed application(s) for same invention (Sections 25 & 26)

| Previous filing date | Country in or for which filed | Filing No. |
|---|---|---|

4. Identification of Inventor(s)
Name(s) of person(s) believed by Applicants(s) to be the inventor(s)

MURRAY, Brian
an Irish citizen of c/o Massana Research Limited, 5 Westland Square, Dublin 2, Ireland

CURRAN, Philip
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MURRAY, Carl
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MOLINA, Albert
an Irish citizen of c/o Massana Research Limited, 5 Westland Square, Dublin 2, Ireland

5. Statement of right to be granted a patent (Section 17(2) (b)) 000320

The Applicant derives the rights to the Invention by virtue of a Deed of Assignment dated April 27, 2000

6. Items accompanying this Request – tick as appropriate

(i) _X_ prescribed filing fee (£100.00)

(ii) _X_ specification containing a description and claims

____ specification containing a description only

_X_ Drawings referred to in description or claims

(iii) ____ An abstract

(iv) ____ Copy of previous application (s) whose priority is claimed

(v) ____ Translation of previous application whose priority is claimed

(vi) _X_ Authorisation of Agent (this may be given at 8 below if this Request is signed by the Applicant (s)

7. Divisional Application (s)

The following information is applicable to the present application which is made under Section 24 –

Earlier Application No: ..................

Filing Date: ..................

8. Agent

The following is authorised to act as agent in all proceedings connected with the obtaining of a patent to which this request relates and in relation to any patent granted -

| Name | Address |
|---|---|
| John A. O'Brien & Associates | The address recorded for the time being in the Register of Patent Agents, and currently Third Floor, Duncairn House, 14 Carysfort Avenue, Blackrock, Co. Dublin, Ireland. |

9. Address for Service (if different from that at 8)

As above

Signed ____________ JOHN A. O'BRIEN & ASSOCIATES

Date April 28, 2000

"Echo and Crosstalk Cancellation"

Introduction

The invention relates to cancellation of echo and crosstalk in high-speed networks such as 1 Gb/s networks.

Taking the example of 1 Gb/p networks, these are typically four pairs, say A, B, C, and D. Each pair (called A, B, C & D) is used for both transmit and receive. Due to mismatches in the cable impedance there is an echo returned to the receiver. These mismatches may occur at junctions and patch cords. In addition, the hybrid only partially attenuates the locally transmitted signal. This combination is know as the echo signal and it appears as a noise source to the receiver.

Because there are four pairs of unshielded cable there is the additional problem of crosstalk. The other three transmitters (at the same end as the receiver) all generate interference signals known as near-end crosstalk (NEXT). Furthermore, the three transmitters at the far end generate interference signals known as far-end crosstalk (FEXT).

In summary, each receiver has to cope with interference signals from seven other transmitters, namely one echo from the transmitter on the same pair, three NEXT from the transmitters on the same end and three FEXT from the three transmitters at the far end.

Heretofore, the approach to deal with these interference signals has been to generate a replica signal to the noise source and to subtract it from the received signal. This is possible because all eight of the transmit signals are known. The corresponding noise signal due to any given transmit signal can be approximated at the receiver using the transmit signal as the starting point. This is usually done using an adaptive transversal filter (adaptive FIR filter - AFIR), one for each of the seven noise sources,

and the input to each AFIR is the corresponding transmit signal. The coefficients of each AFIR are adapted to minimise the difference (MSE - mean square error) between the received signal plus the total noise signal less the output of the AFIR (which is an approximation to the noise signal corresponding to that transmit signal).

The AFIR filter that cancels the echo is known as an "echo canceller", and likewise there are NEXT cancellers and FEXT cancellers. Thus, for a complete gigabit receiver, a total of four echo cancellers, twelve NEXT cancellers and twelve FEXT cancellers are required to cancel all of the noise sources.

A problem with the above approach is that it is a very large and complex system that is expensive in terms of computational complexity, silicon area and power consumption. At a 125 M symbols per second the span of the echo cancellers (i.e. number of taps) is very large, at a 125 MHz sample rate an individual multiplier and adder is required for each tap. In addition a coefficient adaptation circuit is required for each tap. Like wise the span of the NEXT and FEXT cancellers is also very large.

It is known that though the span of an echo canceller required to cancel echo for a given system may need to be very large it is usual that not all of the taps are necessary. The difficulty lies in identifying which taps are necessary and which are not as this will vary from cable to cable and indeed may vary from time to time. This is known to also be a problem in acoustic echo cancellers. A method of tackling this problem has been proposed in WO99/46887 (Broadcom, Gigabit Ethernet Transceiver) where after the echo canceller has been trained a certain number of taps are switched off. A method is described to determine which taps are important and which are not making a significant contribution to the noise reductions. This method has the advantage of reducing the power dissipation of the circuit, though no reduction in area is achieved (in fact area is increased).

The invention is directed towards providing improved echo and crosstalk cancellation.

According to the invention, there is provide an echo or NEXT canceller system for a link having a plurality of cables, the system comprising a canceller for each cable, wherein each canceller comprises a plurality of sections and a variable delay line such that each canceller does not have taps to cover the full span, and the system comprises means for sharing cancellers between pairs such that the full span is available during training.

In one embodiment, each canceller comprises near and far sections and the optimum positions of the near and far sections are determined during training.

In one embodiment, the system comprises means for sharing adaptation circuitry across cancellers.

In another embodiment, the system comprises means for determining delays for near and far, echo and NEXT.

In one embodiment, the system comprise means for combining the output of each section to allow sharing.

In a further embodiment, the system comprises means for separately scaling echo and NEXT signals prior to combining them.

In one embodiment, the system comprises variable delay lines between cancellers.

The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only with reference to the accompanying drawings in which:-

Fig. 1 is a diagram illustrating four cables for a Gb/p network; and

Fig. 2 is a block diagram of an echo canceller of the invention.

Referring to Fig. 1, four cables of a Gb/s network are shown, in which the echo and crosstalk noise is indicated by arrows. An echo canceller is shown in Fig. 2, which requires both less area and power than heretofore. There are four such echo cancellers, and during start-up echo cancellers are shared between cable pairs, allowing smaller echo cancellers to be used during normal operation.

Each echo canceller is composed of two sections, a near and a far section. However it may be split into more than two sections. The sum of the length of the near and far is less than the full span. For example, the full span (required to cancel 100 m of cable) is 160 taps. The near and far may be sections having 40 taps each, a total of 80 taps. A variable delay line is used between the near and far. Also a variable delay line can be used before the near canceller. This is illustrated in Fig. 2, in which the interconnections are as follows.

```
can_ipmux_echo.f_echo_ab_ssz_u = f_echo_dim_a_b.ssz_data_u_out
can_ipmux_echo.f_echo_ab_ssz_l = f_echo_dim_a_b.ssz_data_l_out
can_ipmux_echo.n_echo_ab_ssz_u = n_echo_dim_a_b.ssz_data_u_out
can_ipmux_echo.n_echo_ab_ssz_l = n_echo_dim_a_b.ssz_data_l_out
can_ipmux_echo.n_echo_cd_ssz_u = n_echo_dim_c_d.ssz_data_u_out
can_ipmux_echo.n_echo_cd_ssz_l = n_echo_dim_c_d.ssz_data_l_out
```

During start-up the echo cancellers are trained one at a time, or two or more at a time. Echo cancellers are borrowed from other pairs during training. As an example, EC_A could be trained using the taps from B, and thus the combination spans 160 taps. After training is completed, the taps are examined and the optimum position of the near canceller and far canceller sections is determined and stored (based on finding the taps that contribute most to the noise replica signal). This is done in sequence until all echo canceller are trained. Then all four echo canceller are configured using the variable delay lines and near and far sections and trained again. Now substantially all of the echo is cancelled using much less than the full span of

the echo for all four cancellers due to this technique of sharing cancellers during training. Furthermore this is achieved with savings of both area and power.

A further aspect is to share the adaptation circuit between echo cancellers. It is known that after training has been completed the echo cancellers can be adapted very slowly, as we are just compensating for temperature variations (and the like). In a processor-based system advantage is taken of this to reduce the computational complexity during normal operation, maybe only a few taps are adapted (in sequence) each symbol.

The problem in this case is that it is necessary to be able to adapt at full speed during training, i.e. every tap every symbol. And due to the speed requirements an adaptation circuit must be implemented in silicon for each tap. So though we can save power in normal operation by only turning on some of the adaptation circuits at a time it is not possible to save area.

The invention reduces the area required for the adaptation circuits by taking advantage of the fact that there are four echo cancellers. This allows adaptation circuits to be shared between pairs during training. Hence, each echo canceller is trained one at a time and adaptation circuits are shared so that all taps of the echo canceller can be adapted each symbol. Then during normal operation, when the echo cancellers are all running, the adaptation circuits can be used in sequence for each echo canceller (or in pairs). Thus, the echo cancellers are adapted slowly in normal operation, at full speed in training and a reduction in area is achieved.

The invention is not limited to the embodiments described but may be varied in construction and detail.

Claims

1. An echo or NEXT canceller system for a link having a plurality of cables, the system comprising a canceller for each cable, wherein each canceller comprises a plurality of sections and a variable delay line such that each canceller does not have taps to cover the full span, and the system comprises means for sharing cancellers between pairs such that the full span is available during training.

2. An echo or NEXT canceller system as claimed in claim 1, wherein each canceller comprises near and far sections and the optimum positions of the near and far sections are determined during training.

3. An echo or NEXT canceller system as claimed in claim 1 or 2, wherein the system comprises means for sharing adaptation circuitry across cancellers.

4. An echo or NEXT canceller system as claimed in any preceding claim, wherein the system comprises means for determining delays for near and far, echo and NEXT.

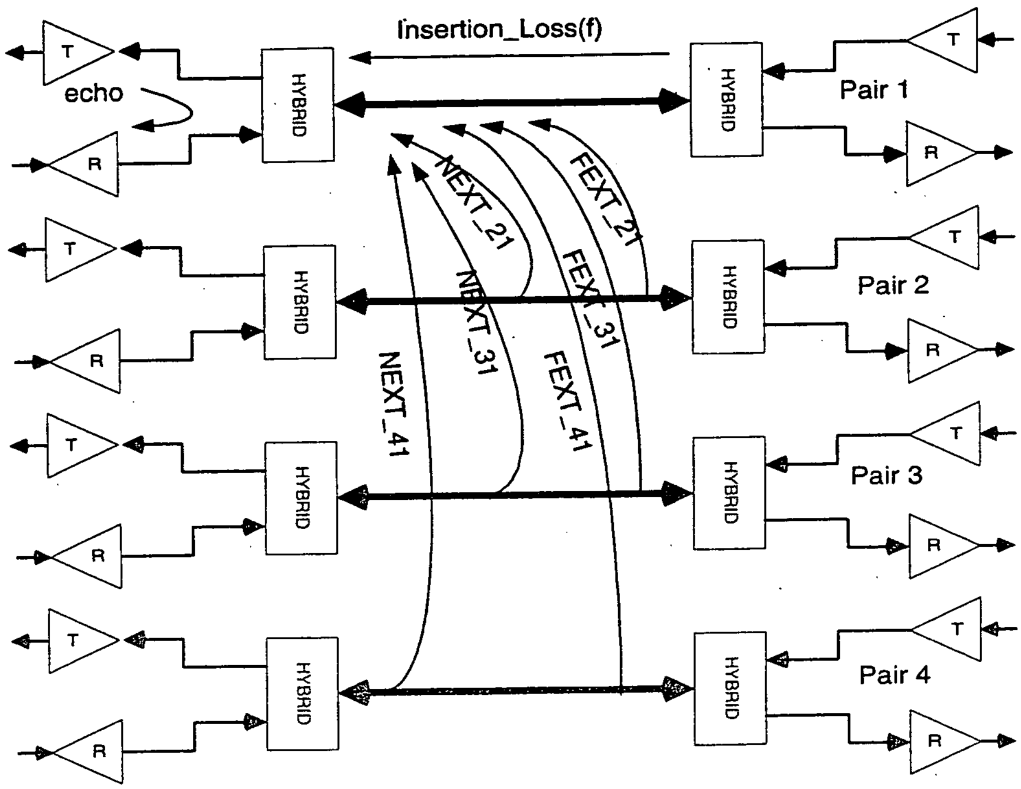
5. An echo or NEXT canceller system as claimed in any preceding claim, wherein the system comprise means for combining the output of each section to allow sharing.

6. An echo or NEXT canceller system as claimed in any preceding claim, wherein the system comprises means for separately scaling echo and NEXT signals prior to combining them.

7. An echo or NEXT canceller system as claimed in any preceding claim, wherein the system comprises variable delay lines between cancellers.

8. A canceller system substantially as described with reference to the drawings.

9. A echo canceller substantially as described with reference to the drawings.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echo
R
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Pair 3
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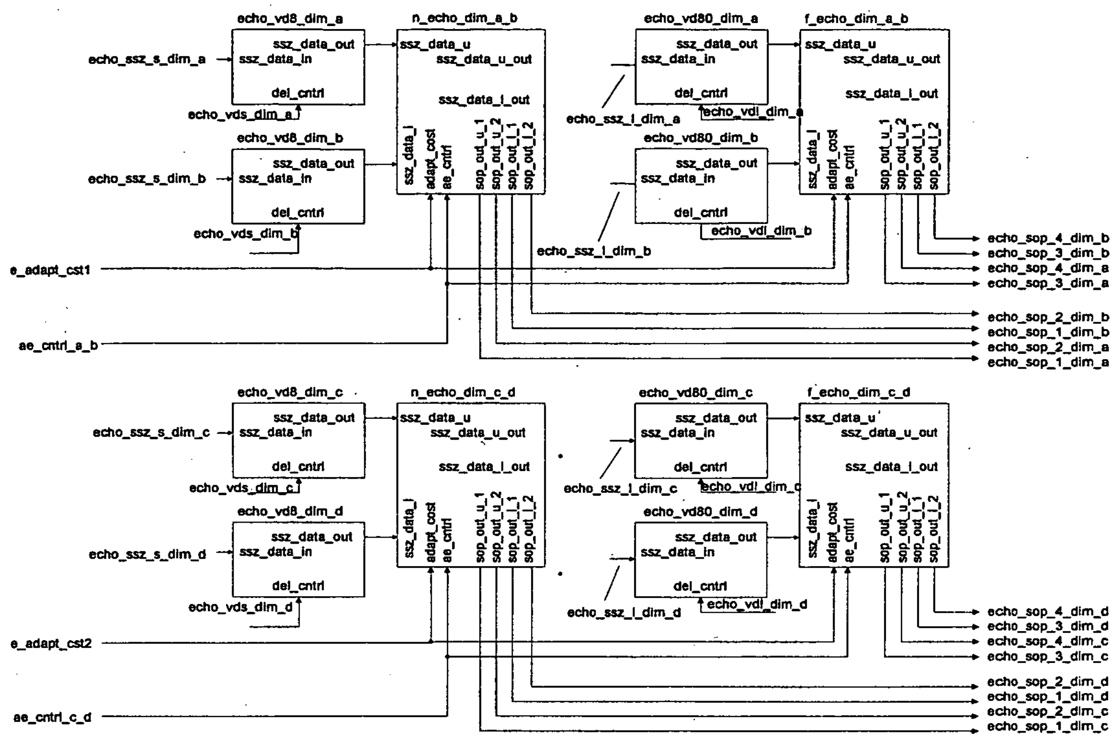
FEXT_21
FEXT_31
FEXT_41

Fig. 1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ssz_data_u
ssz_data_u_out
ssz_data_l_out
echo_ssz_s_dim_a
echo_vds_dim_a
echo_ssz_l_dim_a
echo_vdl_dim_a
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sop_out_l_2
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echo_sop_2_dim_a
echo_sop_1_dim_a
echo_vd8_dim_c
n_echo_dim_c_d
echo_vd80_dim_c
f_echo_dim_c_d
echo_ssz_s_dim_c
echo_vds_dim_c
echo_ssz_l_dim_c
echo_vdl_dim_c
echo_vd8_dim_d
echo_vd80_dim_d
echo_ssz_s_dim_d
echo_vds_dim_d
echo_ssz_l_dim_d
echo_vdl_dim_d
e_adapt_cst2
ae_cntrl_c_d
echo_sop_4_dim_d
echo_sop_3_dim_d
echo_sop_4_dim_c
echo_sop_3_dim_c
echo_sop_2_dim_d
echo_sop_1_dim_d
echo_sop_2_dim_c
echo_sop_1_dim_c

Fig. 2